Chapter 14

The Perception of Space from a Psychological Perspective

Joachim Funke

Introduction

Time and space are fundamental categories for our understanding of the world. Despite the fact that the two categories cannot be separated from one other (time occurs always at given places in space, and space is always space at a certain point in time), I will concentrate in this paper on space (even if recent research shows how deeply space and time are intertwined; see Boroditsky and Ramscar 2002).

There are two levels at which space can be seen from a psychological perspective: (a) the surface level and (b) the deep level. The surface level deals with perception of space based on physiology, mainly physiology of the visual system. At this point we should not forget that we can also locate places by means of hearing, feeling or smelling – accordingly, the physiology of the other sensory systems might also be of interest. The surface level deals with the reconstruction of the environment in the head of a sensing person. But making sense out of perception is more than constructing a three-dimensional inner model of reality. The deep level is occupied with the functional aspects and regards space under aspects like finding food, finding mates, or finding secure places, that is, giving perceptual objects a meaning. The deep, functional analysis deals also with the role of space for our memory (space as external memory) as well as with memory for places. Without the deep level an analysis of space would miss the central issues. Therefore, while anthropologists have to know about the surface level, for a fundamental analysis the deep level is of central importance. However, I will now begin with the former.

Space Perception: the Surface Level

In psychology textbooks on perception (like the famous one from Goldstein 2002), space perception is conceived as an analysis of depth cues, which are available to the eye. There are three types of depth cues that can be used by our eyes: (a) oculomotor cues, (b) monocular cues and (c) binocular cues. We will look at examples of all three kinds of cues.

Oculomotor Cues

Oculomotor cues come from the inward motion of our eyes when we look at nearby objects and the normally parallel viewing axes of both eyes converge; this is called 'convergence' (see Figure 14.1). A second cue is called 'accommodation' and goes back to a tightening of eye muscles, which change the shape of the lens and help to focus on objects we want to see clearly. The ciliary muscles contract the crystalline and thus change the focal length (see Figure 14.2). Both cues – convergence and accommodation – are proprioceptive information, which sometimes (in extreme situations) can be felt consciously.

Monocular Cues

Monocular cues are those which work with one eye alone. Two classes are differentiated: pictorial cues, which can be present in pictures, and movement-based cues, which go back to a head movement.

Pictorial cues are present in almost all pictures. They include occlusion (i.e., one object or part of an object is hidden by another), relative height,

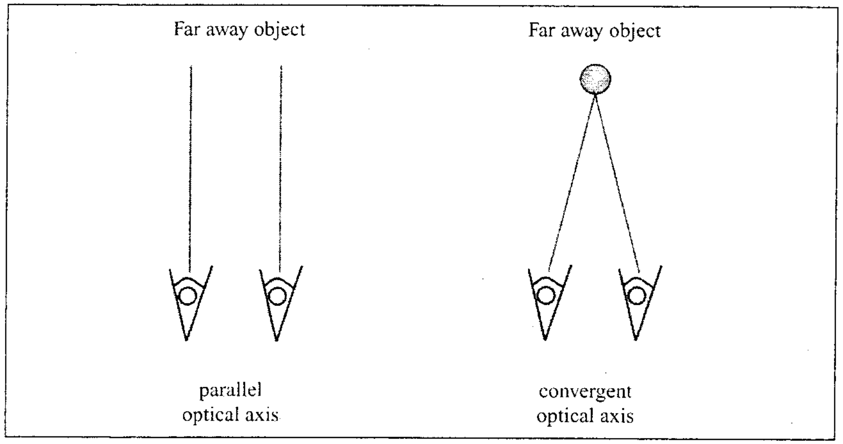

Figure 14.1: Convergence of the eyes: parallel axis for far-away objects (left), convergent axis for near objects (right).

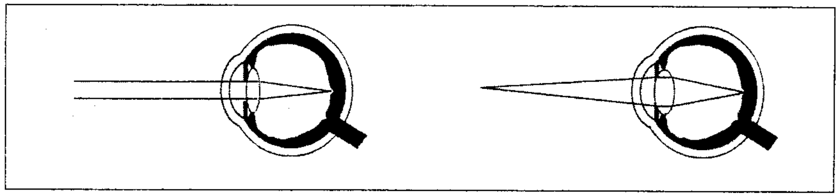

Figure 14.2: Accommodation of the eye. If looking far away (left), the lens is flat; if looking near (right), the focal length of the crystalline changes by means of ciliary muscles.

relative size, cast shadows, linear perspective, atmospheric effects or texture gradient, to mention only the most important ones.

Movement-produced cues are (a) deletion and accretion in overlapping objects which occur during movement, as well as (b) motion parallax which you experience, for example, if looking out of a moving car: near objects glide rapidly past us, more distant objects appear to move more slowly. The speed of the moving objects gives us a signal to their distance; far-away objects move slowly and nearby objects move fast.

Binocular Cues

There is only one depth cue available that requires both eyes: stereopsis. Stereopsis happens because both eyes differ slightly but systematically in what they see respectively. This is due to the fact that the two eyes are around 6 cm away from each other. Fixated points are mapped on corresponding retinal points, whereas objects before or behind the fixation line (which is called a horopter, an imaginary circle that passes through the point of fixation) produce disparity. Figure 14.3 illustrates this effect. This

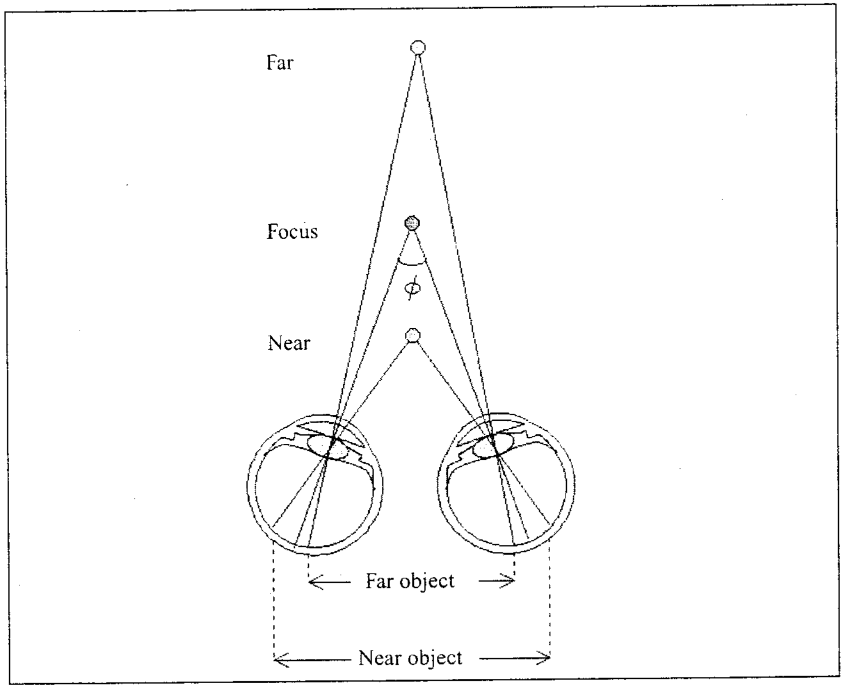

Figure 14.3: A focus point, a near and a far point and their respective placement on the retina. Only the focus point is on corresponding places of the two retinae; the near and far points produce disparity (i.e., noncorresponding places on the retinae), namely the more disparity the further away from the focus point.

disparity can be analyzed in the visual cortex by means of disparity detectors. These detectors allow us to perceive depth in random-dot stereograms in which no other depth cue exists than disparity. You might know random-dot stereograms from those famous books called 'Magic Eye', which contain many of these stereograms; most readers need some experience to see the third dimension; some never reach it because they do not have the ability for stereopsis.

Range of Effectiveness

It is important to know that most depth cues are useful only in a range of maximum 30 metres, some (like accommodation and convergence with maximum 3–6 metres) even less. This means that our visual senses are not made for perception of objects far away, but are specialized for the discrimination of objects in a near radius of 5–30 metres.

Development of Depth Cues

The first experimental studies on this issue were run by Eleanor Gibson in the 1960s with an apparatus called 'Visual Cliff'. This device consists of a glass-covered table and a central platform, from which babies are encouraged to crawl (see Figure 14.4).

Patterns are placed below the glass to create the appearance of a shallow side and a deep side. When trying to get the babies to crawl across the glass, the babies readily crossed the shallow side; but nearly all babies reacted

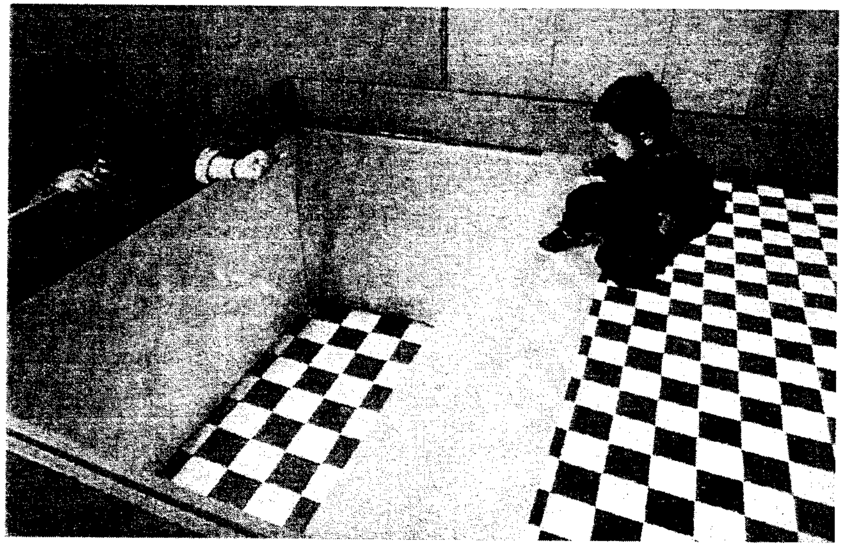

Figure 14.4: A 'Visual Cliff' showing a baby attracted by its mother. A sheet of glass would allow the infant to crawl across the deep section but they stop due to perceived depth.

with fear to the deep side. Gibson concluded that at the time infants crawl, most of them have an understanding of depth perception. Binocular sensitivity emerges in a sensitive time period between two to three months and gradually improves within six months. At seven months, pictorial depth cues lead to specific grasping reactions. Learning of depth cues seems to take place at a very rapid rate during the first three to four weeks of life. It is not completely innate because vision impairments can be compensated for by learning in later years ('vision therapy'). This would not be possible otherwise.

Space Cues from Auditory Information Processing and Other Sources

Up to now, only visual cues for depth perception have been mentioned. But there is also information from both ears, which help to locate objects and say something about the depth structure of one's surrounding based solely on one's hearing. Blind people develop this ability, which is of minor importance if you can see something. But one need not go into clinical examples to get an impression of the power of the ears. Also, space cues can be gained from smell and tactile cues as well (see the chapter by Bettina Beer in this volume).

Gell (1995) reports about the annoying experiences during his fieldwork in Umeda (West Sepik, Papua New Guinea), where he lived for 14 months limited to a sight field not deeper than approximately 10 metres – there was no possibility of seeing the landscape from a panorama perspective. In the dense forest, vision would not help much in hunting but listening did (if you knew what to listen for).

An In-between Summary

What have we learned so far? Perception of space takes place on the surface level depending on our senses. The visual sense mainly, but also hearing (and to a certain degree also movement), contributes to the extraction of certain stimuli from the perceived environment. An anthropologist has to know these facts about the perceptual system – but will that really help to understand space perception? As we will see, a better understanding of space perception will not occur until we enter the deep level.

Space Perception: the Deep Level

To go into the deep level of space perception, one has to go beyond the purely perceptual level. One has to analyse the role of space for a human being. Instead of our previous focus on function, we now have to focus on meaning and significance (which are communicated by language). In a sense, we move on from depth perception to a deeper understanding of spatial cognition (e.g., Montello 2001). The American psychologist Edward Tolman coined the term 'cognitive map' in 1948 to refer to internally represented spatial models of the environment. But as early as the 1920s, the term 'Lebensraum' (in the sense of life-space) was used by the German developmental psychologist William Stern to describe the space in which one lives.

In this early research, some interesting dimensions of life-space have been described which seem worthwhile knowing even today. I follow their description given in Graumann (2002).

Intersubjectivity

Acting in space can become a matter of intersubjectivity. Think, for example, of walking down a street together with your friend. You kick a tin can to him and he responds by kicking the can back. Within seconds, you both agree that the tin can might be used as a soccer ball and the street can be used as your playground. This is possible only because both partners share knowledge about a popular sports game and its requisites. Shared knowledge is equivalent to shared concepts. From there, it is a short way to language, which is the base for communication and therefore the base for establishing intersubjectivity.

Age Specificity

Space perception on the deep level is also dependent on age. Taking an example from Graumann (2002), a junior might climb upon or jump over an object which is seen as an obstacle from a senior person's perspective. Older people (especially those suffering from impaired mobility) explore their environments quite differently from toddlers who enter every place they can. These examples demonstrate how affordances of objects change with age.

Gender Specificity

In the same way that people of different age perceive the space around them differently, so also do the two sexes perceive space in a gender-specific way. If we talk about gendered environment, we make reference to the gender-specific attractiveness of certain places. In a big store, gender-specific preferences can be observed very easily with women strolling through the clothes departments and men exploring the tools section (I apologize for stereotypes!). The attractiveness of certain places like brothels is clearly gender-specific. Therefore, certain places are explored more probably by men than by women; other places the other way round – more by women than by men. In a certain sense, this gender-specificity reflects the differentiation of gender in a given society. Also, religious systems sometimes make prescriptions about places that are reserved for one sex only.

From Space to Place

Some researchers think of space as chaos and of place as order. I would argue that there is a change from anonymous space to personal places by a process called 'Aneignung' (appropriation) by Graumann. Appropriation of space occurs, according to Graumann:

> by marking, naming, defining, categorizing, and evaluating space as appropriate or inappropriate, owned or free, by signs, words, rules, regulations, and laws; but also by regular locomotion resulting in paths and roads; by the cultivation of nature as subsistence or supply of resources; by the domestication of animals; by the conquest of foreign land and the subjugation of other people(s); by building, constructing, and settling; but also by the artistic and scientific representation of space; and finally, by the overcoming of distance by developing means of communication. (2002: 104)

This enumeration of different types of 'Aneignung' demonstrates the many ways for humans to make places out of space. They are all ways to give space a special meaning. Therefore, space perception at the deep level requires an analysis of personal memories for certain places. At this level, one cannot separate the perceptual processes from human memory. In a sense, research on space perception is research on memory for places.

'Space Games': Psychological Considerations

This last part of my paper will give some recommendations to researchers who plan to work with 'Space Games' (see, e.g., Levinson 1992). The Space-Games Kit contains special instruments to elicit task-oriented verbal space descriptions in cross-linguistic fieldwork situations. Following the description given by Senft (2003; see also Senft in this volume), those games involve a 'Director' consultant who sees a certain stimulus, and a 'Matcher' who does not see it. Director and matcher are sitting side by side separated by a screen so that they cannot see each other's stimulus (Fig. 14.5).

In the Tinkertoy Games, for example, the matcher has to build a three-dimensional configuration with the help of the Tinkertoy building blocks, based on the director's description of the original placed before him (either as an object or – even harder – as a photo of the object).

In the Animal Game, as another example, three different animals are placed in a row by the director and have been reproduced by the matcher on a table which is turned by 90° or 180° to the original. Based on the reconstruction of the original, geocentric or egocentric representations can be assumed (see Wassmann and Dasen 1998).

The following recommendations concerning the use of Space Games may seem to be trivial to psychologists, but may be helpful for anthropologists. I have formulated eleven theses for this purpose.

Thesis 1: Memory Is a Representational System

Memory is not a storage or accumulator of events which you put things into to get them out later. Memory is an *active* system, which uses representations: for words, for pictures and for sequences. Representations for words can be found in propositional systems, for example, in associative priming (Tulving and Schacter 1990). Representations for pictures can be

Figure 14.5: Director and matcher working with photographs on both sides of a screen.

found in analogue systems, for example, in mental rotation (Shepard and Metzler 1971). Representations for sequences are necessary to store the succession of events, for example as scripts (Schank and Abelson 1977). Besides these three representational formats, which go back to Anderson (1985) and others, there might be additional representational formats for specific memory entries (e.g., for motor representations). But one should be careful not to assume too many representational formats because it cannot be expected that nature is organized around a representational 'zoo' with many different exemplars.

Representations transform reality. They transform reality during encoding and during recollection under control of attention and proto-/stereotypes. This is the reason why some people say memory is 'schematic'. Different types of representations support different types of processes: if you want to represent the relation between different objects in space, analogue representations might be much more useful than propositional ones. That is the reason why a picture says more than thousand words.

Implications for Space Games: Because Space Games require memory and representations one has to think about the necessary type of representation in a certain experimental condition. It should be clear that the importance of analogue representations might be greater than that of propositional representations if the stimulus material contains analogue dimensions (e.g., different sizes).

Thesis 2: Not All Cognitive Processes Are Conscious

Since Freud, it is not only psychologists who are aware of the importance of unconscious processes, even if we nowadays are sure that his restriction of the unconscious only to sexual impulses is too narrow. The distinction between conscious and unconscious parts of knowledge has been elaborated by Ryle (1949), who said that we have to distinguish between 'knowing that' ('Wissen'), which is declarative knowledge, and 'knowing how' ('Können'), which is procedural knowledge (or even better, 'knowing'). That knowledge does also have a spatial dimension (in terms of concentration of knowledge and professional skills at certain places), is explained in more detail by Meusburger (2000).

Today's research on implicit and explicit learning as well as on implicit and explicit memory (Reber 1967, 1989, 1992; Schacter 1987, 1992, 1999) shows us impressively strong influences of unconscious representations on human behavior (see also Stadler and Frensch 1998).

Implications for Space Games: They measure to an unknown distribution explicit (conscious) and implicit (unconscious) processes at the same time. One has to think about procedures (nonverbal tests), which would differentiate between implicit and explicit parts of the shown behaviour. That automatic processes are unconscious and not available to the subject implies the uselessness of verbal answers – if one asks one *will* get an answer but would one really trust in it?

Thesis 3: Also Nonverbal Tasks Tap Language

There is a difference between verbal and nonverbal tasks in terms of the output system, but not of the internal system. 'Mentalese', a term coined by Steven Pinker (1994) for the language of the brain (which is independent of spoken language), is always needed if someone does something in a conscious, deliberate way (for a fundamental critique of this conception see Fodor 2001).

Implications for Space Games: Researchers should think about automatic and controlled processes. Automatic processes (e.g., perception) can never be verbalized. Control processes *can* be verbalized (e.g., problem solving) but might be disturbed due to verbalization.

Thesis 4: Instructions Need to Be Understood

In every field situation, subjects have to be instructed how to behave. These instructions have to be given for verbal and for nonverbal tasks. One lesson that can be learned from psychology is that subjects can misunderstand or interpret instructions differently from how the experimenter wants them to be understood.

Implications for Space Games: Researchers should ask subjects afterwards how they understood the task and what procedure for solving the task seemed appropriate to them.

Thesis 5: Not Every Answer of a Subject Is True Data

In psychology, there has been for a long time an awareness of the fact that measurements can be decomposed into true values and measurement error. If a subject, for example, shows an IQ of 100, nobody would believe that this is the true value – the true value lies in a range between 95 and 105, depending on the reliability of our measurement instrument. In eyewitness testimony, psychologists are aware of the fact that in recognition tests not every recognized item reflects true recognition. Signal detection theory (SDT; see, e.g., Swets, Dawes and Monahan 2000) offers a methodology to separate the sensitivity of a subject from his or her bias. By means of 'catch trials' it can be assessed how precisely a subject reacts to the stimulus material. Counting the hits, the misses, the false alarms, and the correct rejections makes it possible to simultaneously assess sensitivity and bias of the responder.

Implications for Space Games: Researchers should think about and allow for measurement error and they should think about application of tools like signal detection theory to separate sensitivity from bias. A 'yes, this one' can be everything from a blind guess to secure knowledge.

Thesis 6: 'Labilization' of Subjects Might Occur

Holzkamp (1972) was one of the first who criticized psychological experiments because of their social asymmetry. He argued that the experimenter is always a person who knows about the next steps and who can manipulate the subject for the next 30 minutes, or whatever time the experiment might take. This social asymmetry leads to what he called 'labilization', a situation in which a dependent subject looks for any cue that might help to reduce his or her uncertainty.

Implications for Space Games: Space Games are a highly social situation because the director or manager has the knowledge and the power, gives commands, and has hidden plans. The matcher is a dependent person, is prepared to follow commands, and is uncertain about the plans of the director. This will influence the collection of data, the amount of data as well as the type of data.

Thesis 7: Not Only Data But Also Models Are Needed

Anthropologists like to collect data in the field but sometimes it is necessary to become aware of the fact that data become powerful only in light of theories or hypotheses. Such hypotheses could be related to the assumed representation of the task or to processes, which might be possible with a certain task representation (e.g., mental rotation). Hypotheses might also help to clarify the effect size which determines the amount of subjects needed: if I look for a very small effect size, then I need larger samples whereas if I look for very large effects these can be found with relatively few subjects.

Implications for Space Games: Useful instruments, which might help to think in terms of models, could be task analysis (e.g., is a task positional where space is primary, or is a task relational, where relations are primary?) and cognitive modeling. Cognitive modeling might help to answer the question how would a machine solve a task and what would a machine need to solve a task. Also, lessons from robotics are interesting. The famous 'Robo Cup' (see http://www.robocup.org/) gives an example of how machines which play a kind of soccer communicate their position on a soccer field. According to Christian Freksa (C Freksa 2003), it turns out that geocentric data are easy to communicate but egocentric data are cheap to update. This differential function should be kept in mind.

Thesis 8: Contextuality Is a Major Feature of Human Beings

Humans are highly contextual beings. A simple experiment by Olson (1970) gives a good example of that. Subjects are given a wide round block and are asked to name this object. If it is presented alone, subjects call this object 'the block'. If it is presented in the context of a black block it is called 'the white'. If it is presented in the context of a white square, it is called 'the round'. If it is presented in the context of different other objects, it is labeled the 'white round'. There are many other studies showing the high dependence on context of the cognitive system.

Implications for Space Games: Look out for context effects even if you do not think that context might influence your results. For example, change the animals in the animal-in-a–row task to see if subjects are sensitive to this kind of context.

Thesis 9: Take Care for Perspectivity

Perspectivity is also a general feature of human beings. This feature has been described in more detail in the previous section and does not need elaboration here. As mentioned before, intersubjectivity, age specificity and gender specificity are important aspects. The research done by Wassmann and Dasen (1993) gives good examples of the control of different perspectives.

Implications for Space Games: Researchers should provoke *different* perspectives, for example, compare rural versus village people, young versus old people, male and female people. Also, social status might establish a certain perspective, which might influence data collection.

Thesis 10: Emotionality of Space Has to Be Accepted

Even if it can be assumed that Space Games are primarily a cognitive task we are now sure, for psychological reasons, that even in purely cognitive tasks emotions are present and show their influence. There is a strong connection between cognitive and affective processes.

Implications for Space Games: One should always think of potential influences from the affective side. One could think of using intentionally affectively laden objects to explore the reactions of subjects when confronted with objects in the Space Games that are not neutral.

Thesis 11: Episodic Memory Implies Space and Time

The term 'episodic memory' was coined by Tulving (1972) in contrast to what he called 'semantic memory'. Episodic memory was conceived as that part of memory which makes the recollection of an episode possible in terms of time and place. Semantic memory is the kind of memory that contains knowledge that is not primarily related to the place and time at which it was learned.

Implications for Space Games: Users of Space Games should be aware that it is not only space that plays a role in these games but also time – for example, which of the animals was placed first in the row, which was placed second and which third. This implicit time axis might be made explicit if one changes the task, for example, so that subjects have to remember what was the first animal placed on the desk.

Conclusions

What implications do these psychological insights have for anthropologists? Is there anything to learn from psychologists' research on space perception?

Psychological research about the surface level of perception demonstrates the existence of a large number of pictorial depth cues, most of which seem to be the result of learning processes. The use of pictorial stimuli takes for granted that subjects can use these cues as we do. If we hear that the use of perspective in painting was discovered as late as the fifteenth century in our Western culture, we have to acknowledge the fact that this type of depth cue is not self-evident and requires an environment full of these cues!

Anthropologists sometimes ask if space representation is geocentric or egocentric. This may be the wrong question. A flexible system like the human brain can switch between different modes of representation depending on their usefulness for a given task. Therefore, it is much better to ask under which conditions native subjects prefer which sort of representation and to find out which type of representation is dominant in a certain culture (e.g., Wassmann and Dasen 1998). One also has to think about tasks, which are easier to solve when using one type of representation rather than another.

For an experimental psychologist there is also one standard question to the experimenter: How do subjects understand the instructions? In psychology, we know of many situations in which the experimenter *wanted* subjects to understand the task in a certain way but the subjects understood it in another way. With Space Games, one has to clarify very carefully how subjects understand the task: 'Reproduce the same arrangement of objects *here*, which you have observed *there*.' The fact that

certain cultures interpret such a task in their way (e.g., geocentric) does not exclude the possibility that they could also understand the other interpretation of that task (e.g., egocentric). Researchers might register the preferred mode of representation but should not conclude rashly this is the only mode.

Psychological research about the deep structure of perception shows the importance of criteria like intersubjectivity of space, age specificity, or gender specificity. With respect to Space Games it becomes evident that these instruments might, for example, help to elicit words used for certain directions or locations as well as actions related to spatial tasks. But Space Games cannot uncover space perception on the deep level. To do that, it is necessary to see how people appropriate their environment ('Aneignung'), how they turn space into place.

Experiencing New Worlds

Edited by
Jürg Wassmann and Katharina Stockhaus

Berghahn Books
New York • Oxford
2007